AD-A189 812 METAL OXIDE VARISTOR POLARIZATION FROM AN INITIAL TRANSIENT(U) AIR FORCE WEAPONS LAB KIRTLAND AFB NM D H HILLAND AUG 87 AFWL-TN-86-58 1/1

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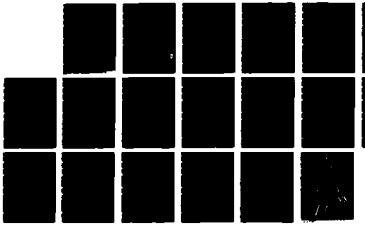

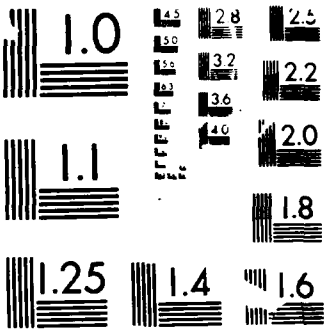

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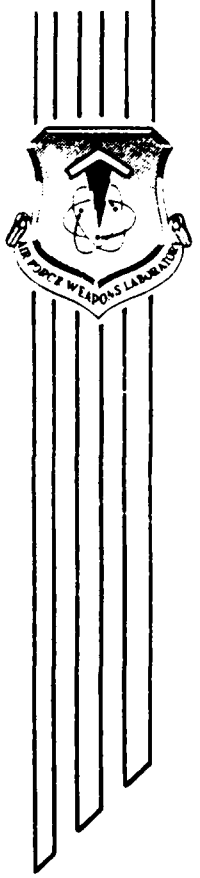
METAL OXIDE VARISTOR POLARIZATION FROM AN INITIAL TRANSIENT

D. H. Hilland

August 1987



Final Report

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AIR FORCE WEAPONS LABORATORY
Air Force Systems Command
Kirtland Air Force Base, NM 87117-6008

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DAVID H. HILLAND
Project Officer

FOR THE COMMANDER

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Capt, USAF
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19. ABSTRACT (*Continue on reverse if necessary and identify by block number*)

Metal oxide varistors (MOV's) are polarized by the initial transient shunted. This effect is seen in the early part of the current - voltage (I-V) curve as a decrease in clamping voltage and increase in standby current. The magnitude of degradation is a function of the measured polarity relative to the pulse polarity of the initial transient. This report presents alpha and I-V degradation curves for all sizes of MOVs tested.

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1.0 INTRODUCTION

Earlier work (Ref. 1) has shown that metal oxide varistors (MOVs) undergo polarization from the initial transient shunted by the MOV. This is evident from the change in the initial current-voltage (I-V) curves as a function of pulse polarity. Subsequent data analysis presented here shows the effect of this form of degradation on the current-voltage curves for all five sizes of varistors tested along with the respective degradation of alpha, the figure of merit for the degree of nonlinearity of the MOV. The decrease in slope of the early part of the I-V curve shown in Figure 1 is the result of the initial burn-in of the device. Further clarification of the effects of polarization is developed here.

2.0 DISCUSSION

Recall from Reference 1 that five samples of five types of MOVs were tested by measuring the initial I-V curves of new devices, then subjecting each varistor to a series of pulses at or near the rated energy level for the device. Initial data analysis indicated that the pulse polarity of the initial transient was an important factor in determining the amount of change in the I-V curves. Figures 1 through 22 show the initial I-V curves compared with the I-V curve after one pulse for the test devices as a function of device polarity. The pulsed polarity is indicated with each figure.

Figures 1 through 5 show I-V characteristics for an MOV rated at 0.13 J (Ref. 2), with a nominal clamping voltage, $V_{N(DC)}$ equal to 33 V at 1.0 mA DC. This was the smallest of the MOVs tested. Figure 1 shows a device which was pulsed in the "positive" direction (the initial polarity assignment is arbitrary) and measured in both the positive and negative directions. The data curve for the negative polarity measured after one pulse is somewhat lower than the curve for the positive polarity measured after one pulse. Figure 2 shows a better example of this effect. The burn-in (i.e., after one pulse) I-V curve opposite to the pulsed polarity is significantly lower than the curve measured in the pulsed polarity. Error bars are included. Figures 3, 4, and 5 show similar results. Note that the apparent polarization is in

the early part of the curve and may not affect the final clamping voltage at higher currents. The curves do indicate that the MOV is conducting more current after burn-in, and corresondingly more power is dissipated by the device at lower currents. The nonlinearity of the MOV has been decreased by the initial pulse.

Figures 6 through 10 show I-V characteristics for an MOV rated at 8.8 J (Ref. 2), with a nominal clamping voltage, $V_{N(DC)}$ of 47 V at 1.0 mA DC. Again the results are consistent. Figures 7 and 8 show opposite pulsed polarities with the lowest curves being measured opposite to the pulsed polarities, indicating the greatest amount of degradation from burn-in in the polarity opposite to the pulsed polarity.

Figures 11 through 14 show I-V characteristics for an MOV rated at 140 J with $V_{N(DC)}$ equal to 430 V at 1 mA DC. Figure 12 shows the only curve on the group with significant polarization. Figures 11, 13, and 14 are consistent with the polarization findings. However, the lower burn-in curves are within the error bars for the I-V measurements. So, the results of these three figures are inconclusive.

Figures 15 through 19 show I-V characteristics for an MOV rated at 130 J (Ref. 2), with $V_{N(DC)}$ equal to 390 V at 1 mA DC. The I-V curves for Figures 15, 17, 18, and 19 show familiar results. Figure 16 appears to have an anomaly in the initial negative curve. The negative burn-in curve, however, is the lowest curve as expected.

Figures 20 through 22 show I-V characteristics for the MOV with the highest energy rating of all devices tested. This device was rated at 200 J (Ref. 2), with $V_{N(DC)}$ equal to 200 V at 1 mA DC. These energy ratings were high enough that the device only shows degradation in the form of polarization in the direction opposite to pulsing. The burn-in curve for the pulsed polarity is essentially unchanged. Again it can be seen that all curves approach the initial I-V curves, indicating that the polarization is most pronounced at early times and lower currents.

The varistor figure of merit, alpha, also decreases with burn-in and as a function of the measured polarity relative to the pulsed polarity. A set of alpha curves which illustrates the effect is included in the Appendix. Note that the alpha of the device appears to increase with subsequent pulsing in a significant number of the devices. The voltage data at 0.5 and 1.0 mA were used in calculating alpha. This may be a result of the device "settling down" with subsequent pulsing as the dipolar molecules in the intergranular matrix become aligned. However, no work has been done to investigate this effect.

3.0 CONCLUSIONS

The MOV is polarized by the initial burn-in transient. This polarization may result in a slower turn-on time, and consequently, a larger portion of the transient reaching the critical load which the MOV is protecting. This uncertainty should be considered when selecting an MOV for a particular application. The amount of both burn-in degradation and polarization is a function of the energy in the burn-in transient, so overdesign should insure that the MOV will not shunt a transient with an energy rating close to the MOV energy rating.

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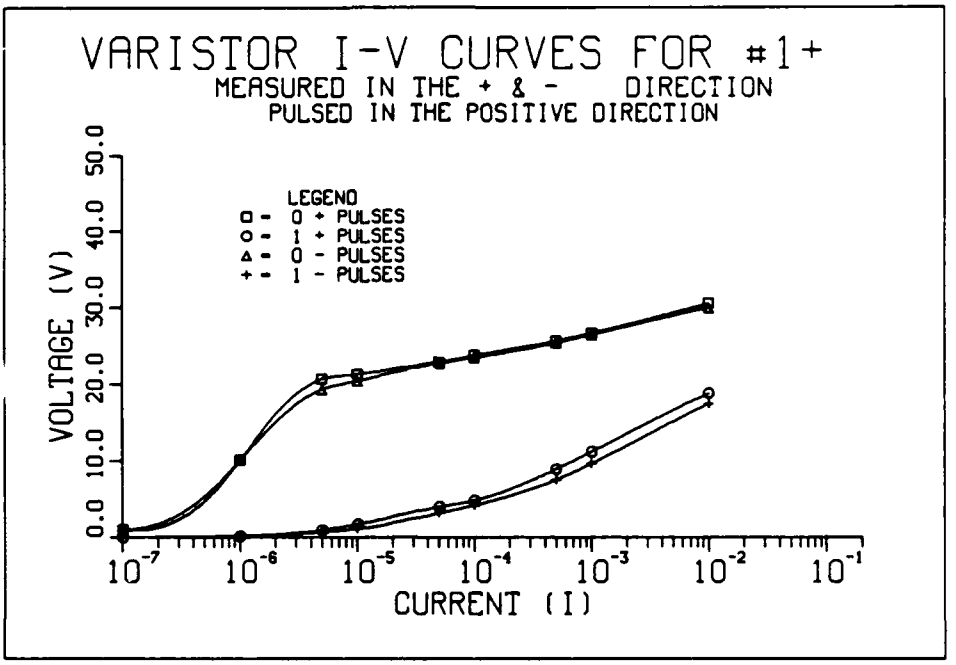

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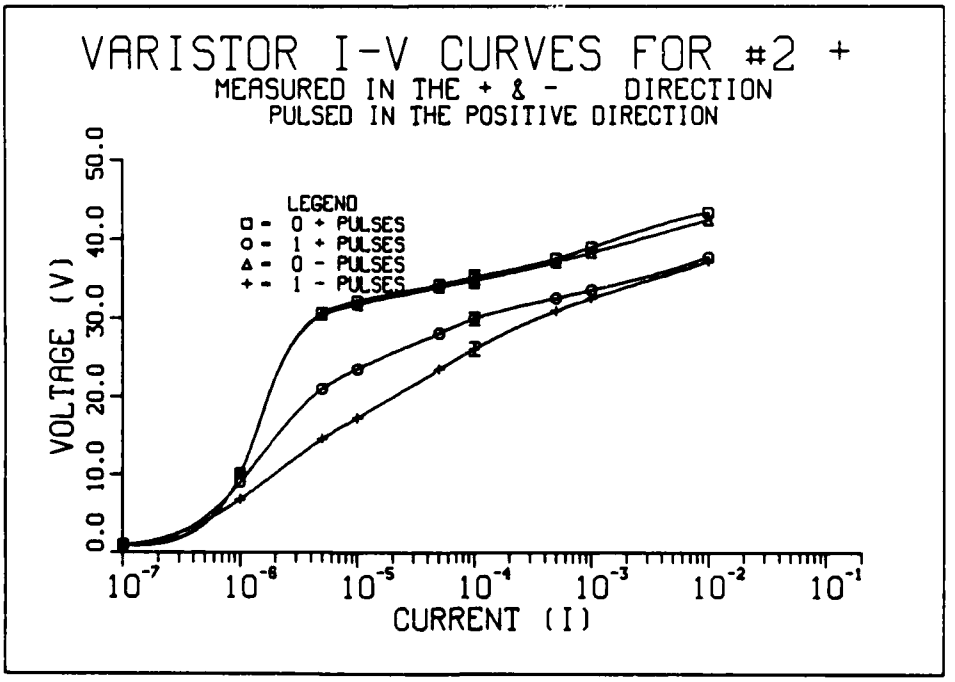

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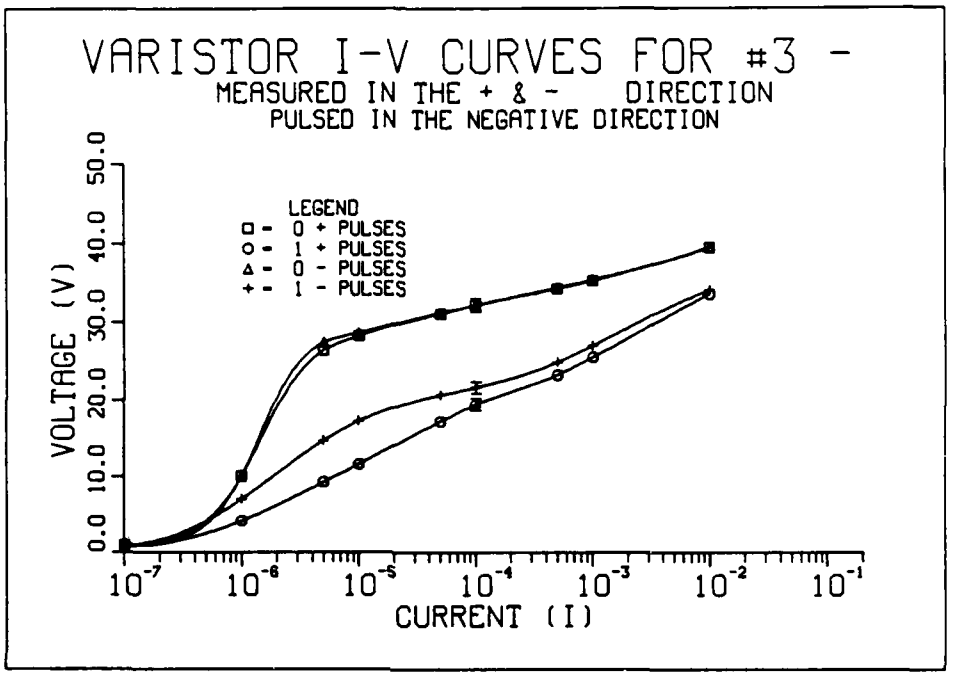

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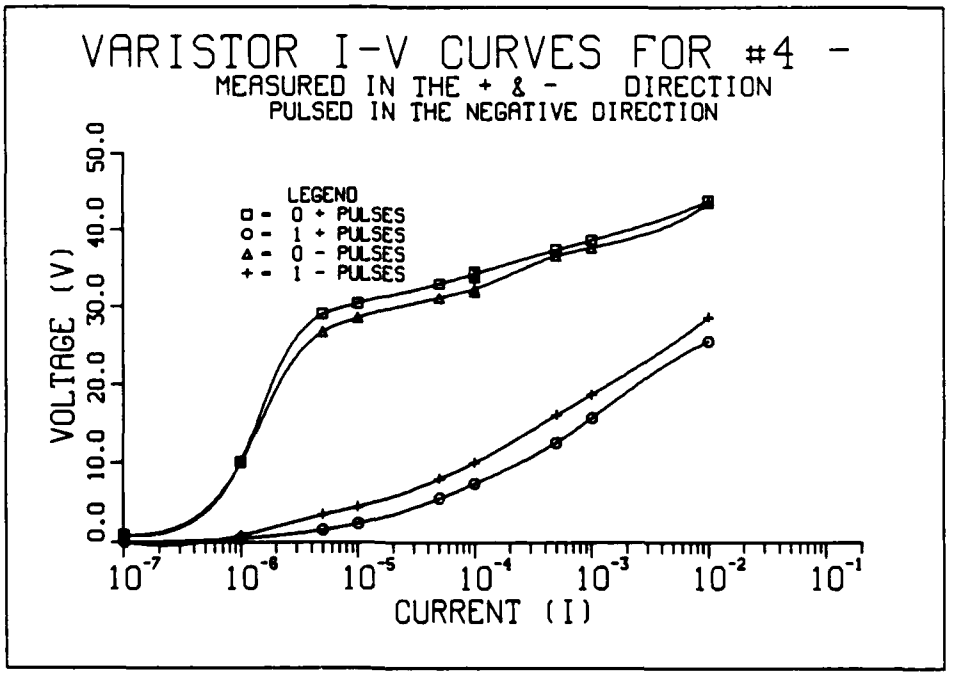

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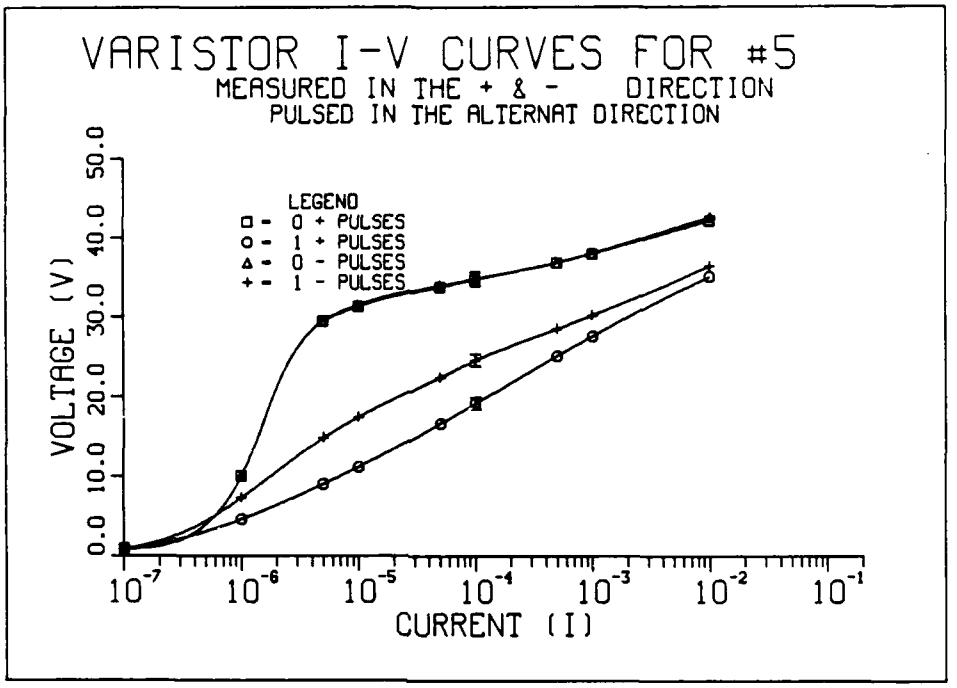

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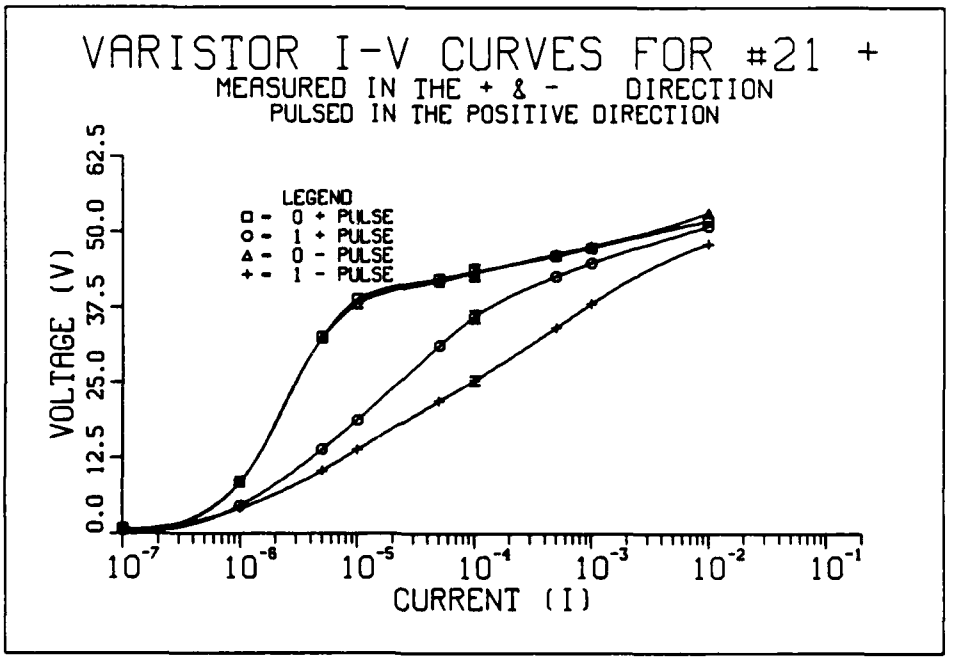

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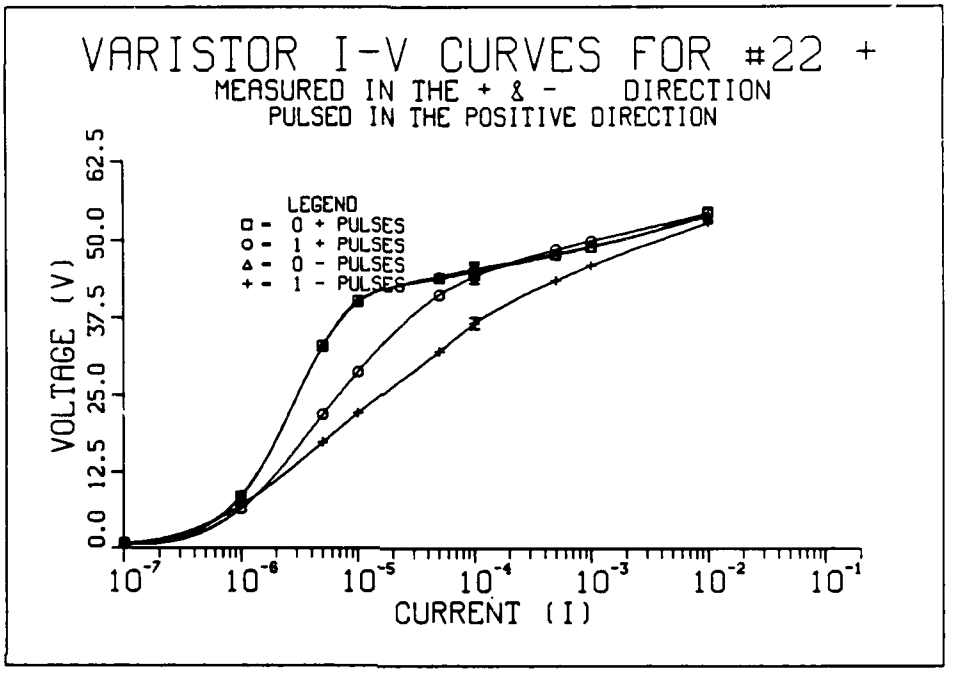

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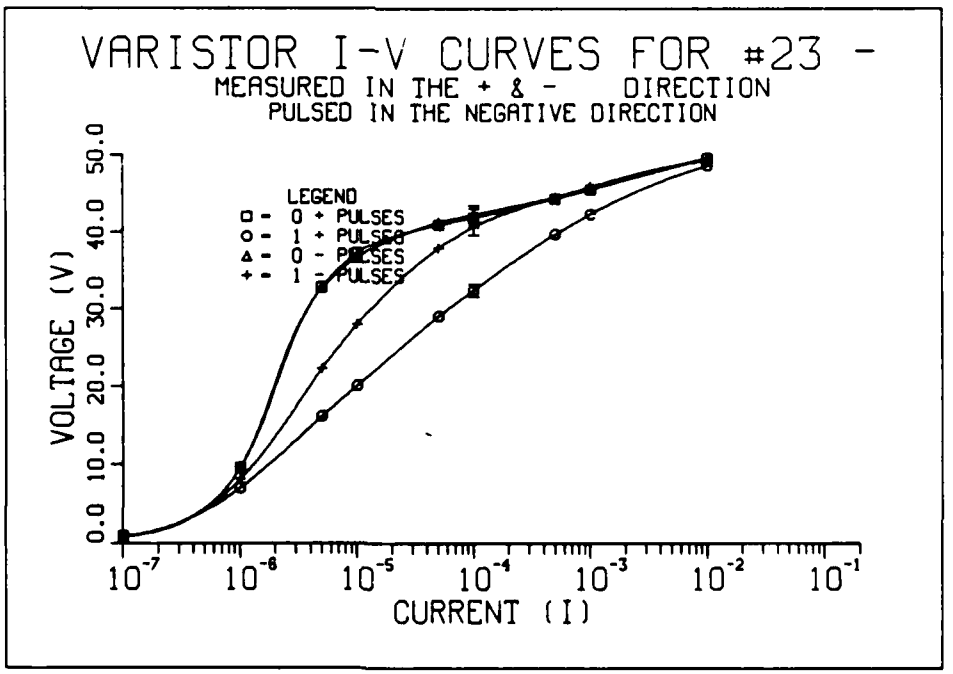

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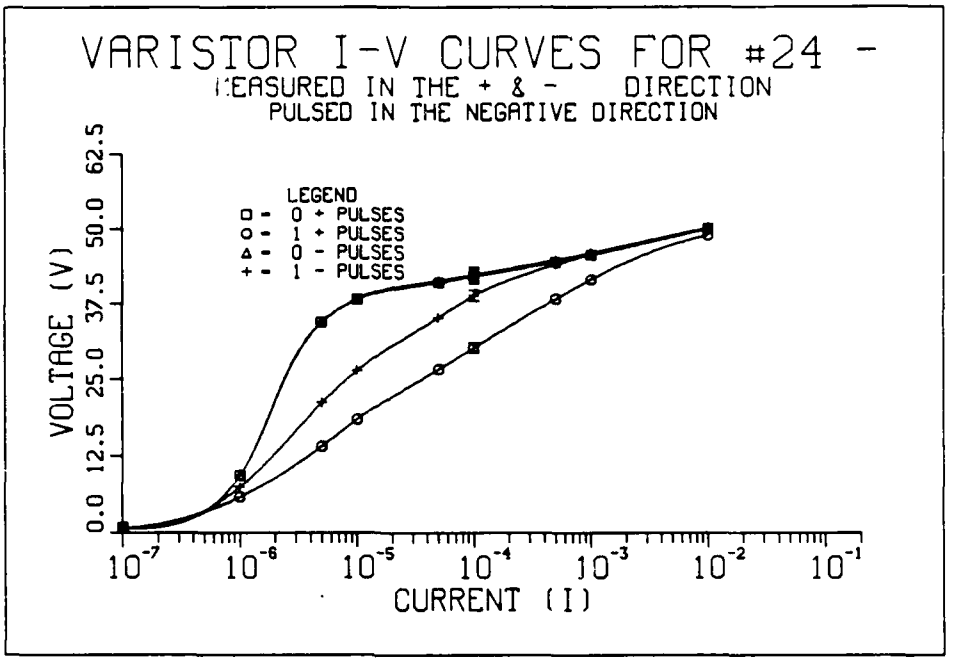

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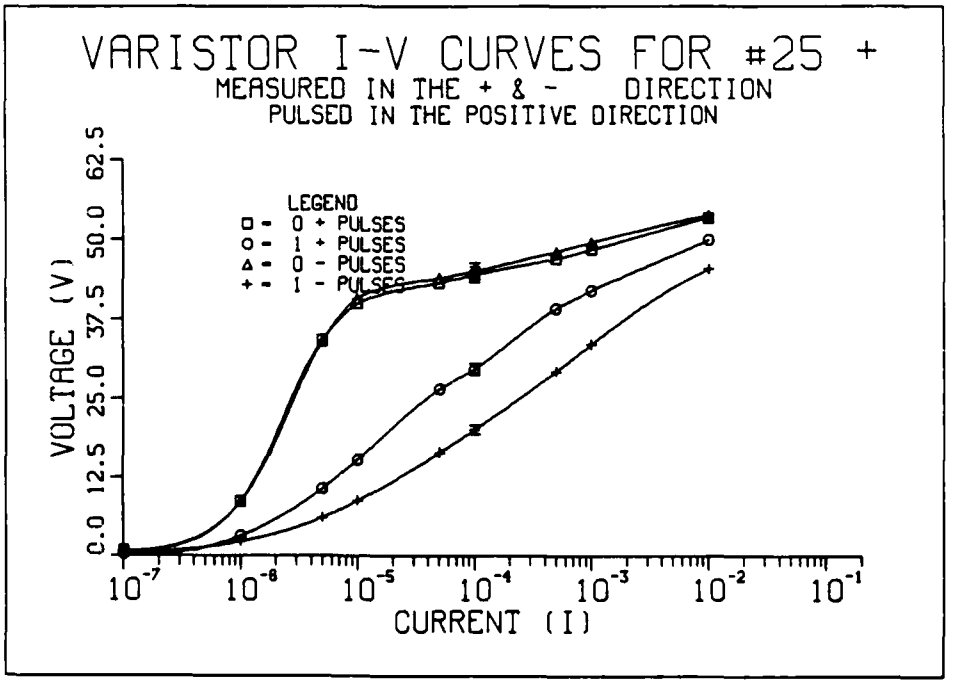

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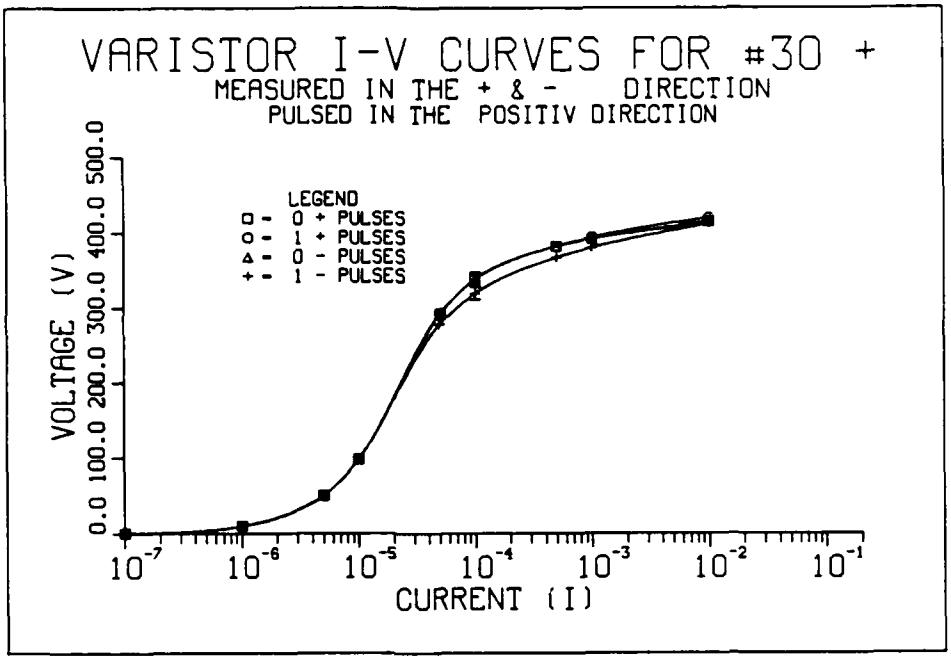

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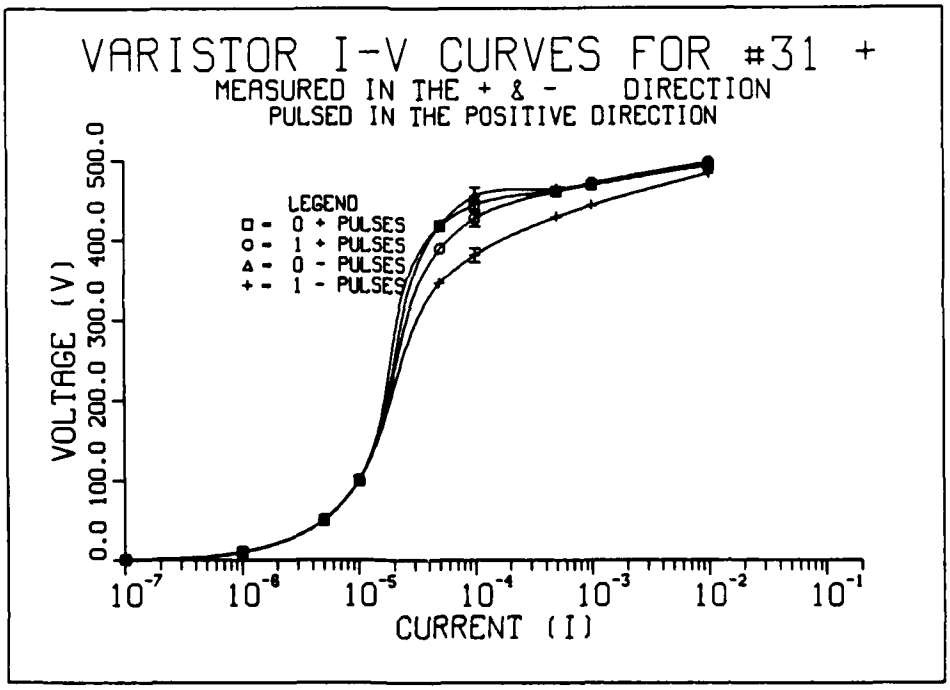

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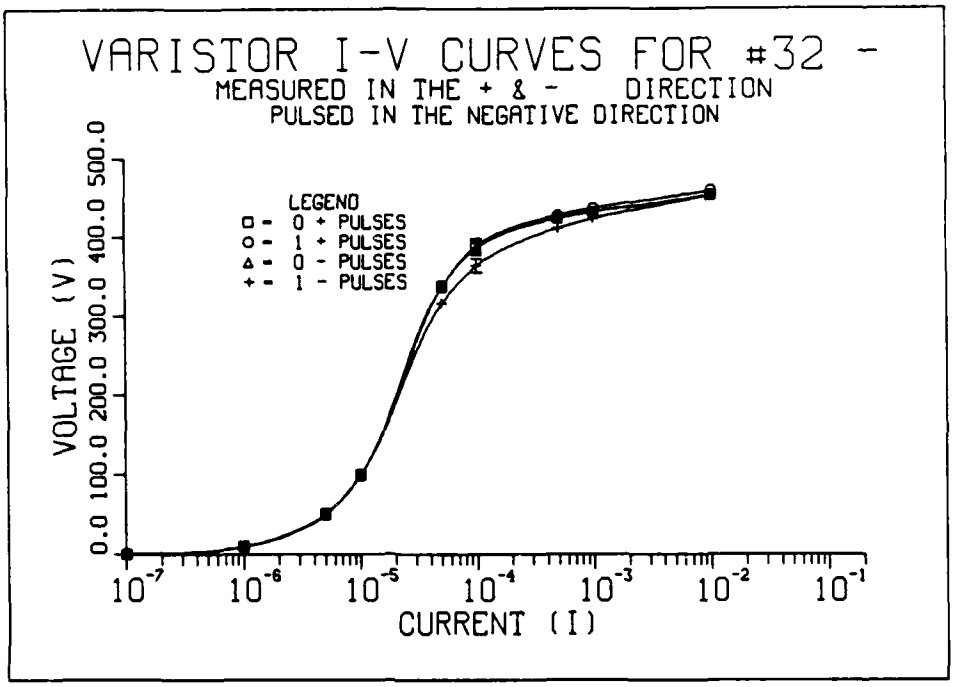

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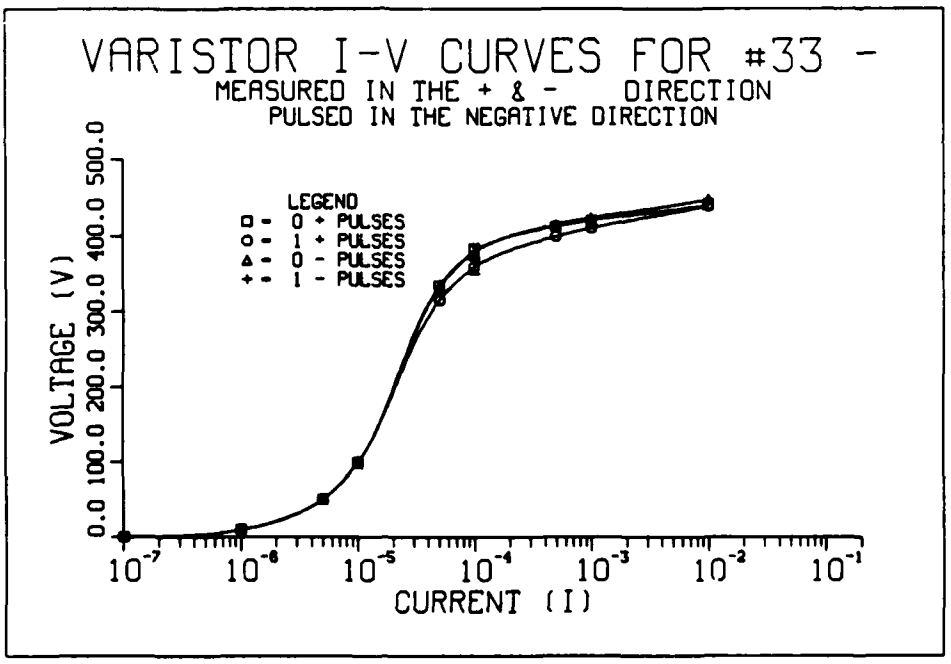

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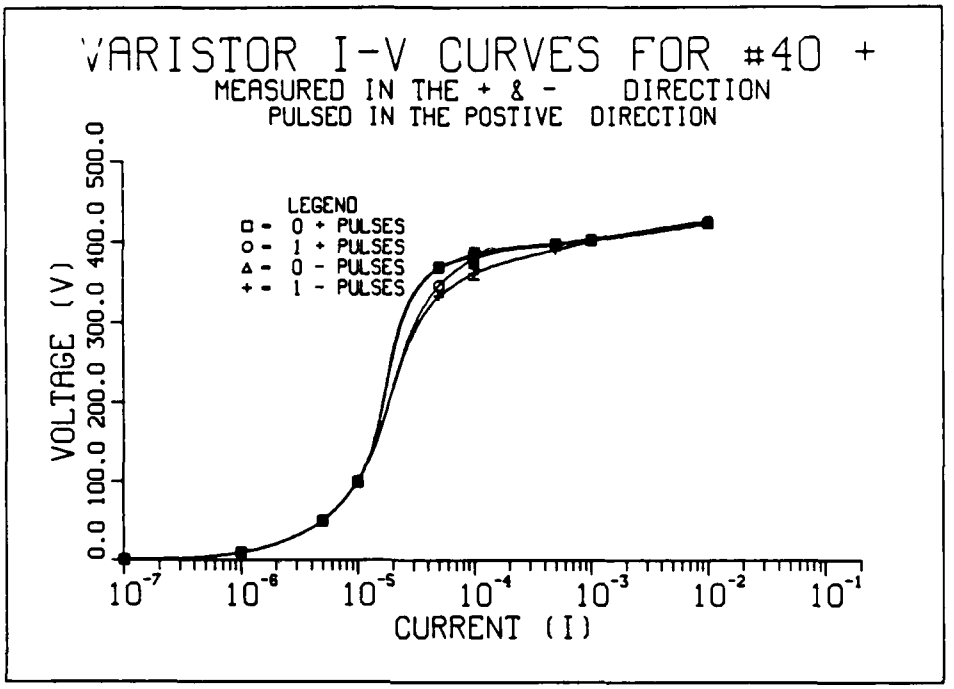

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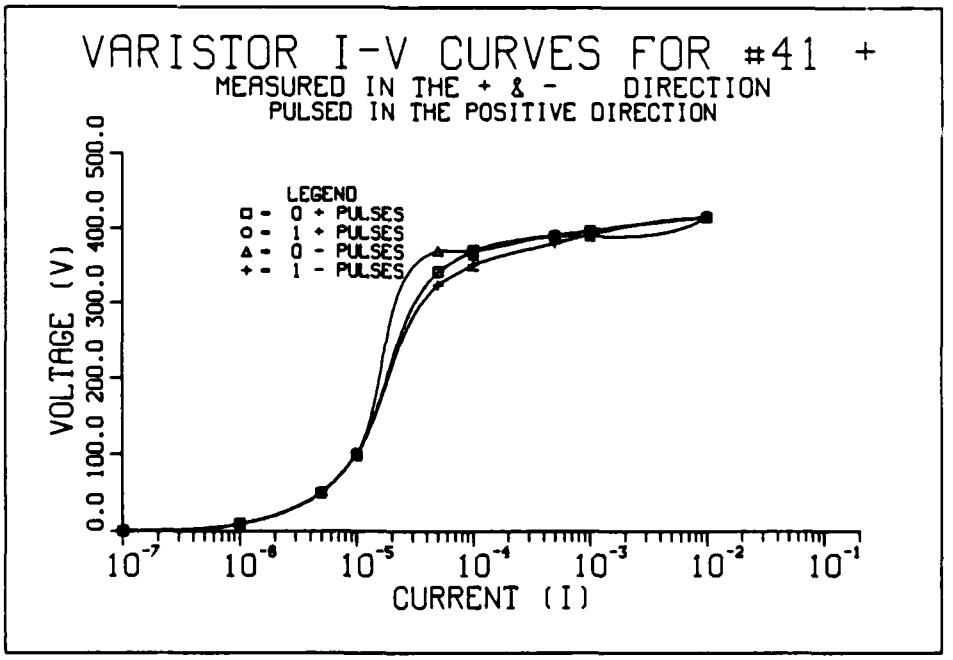

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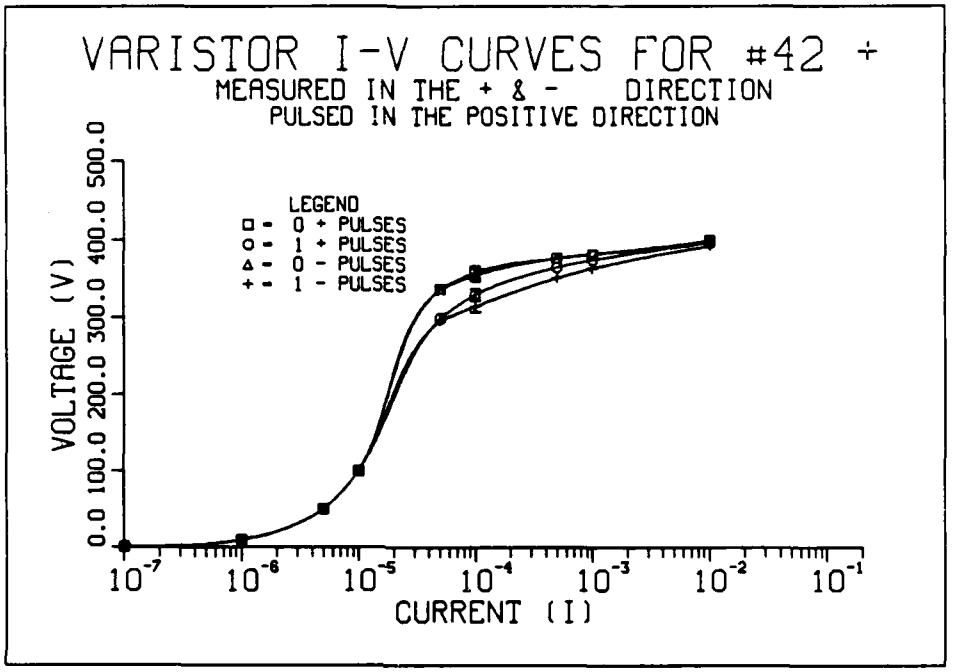

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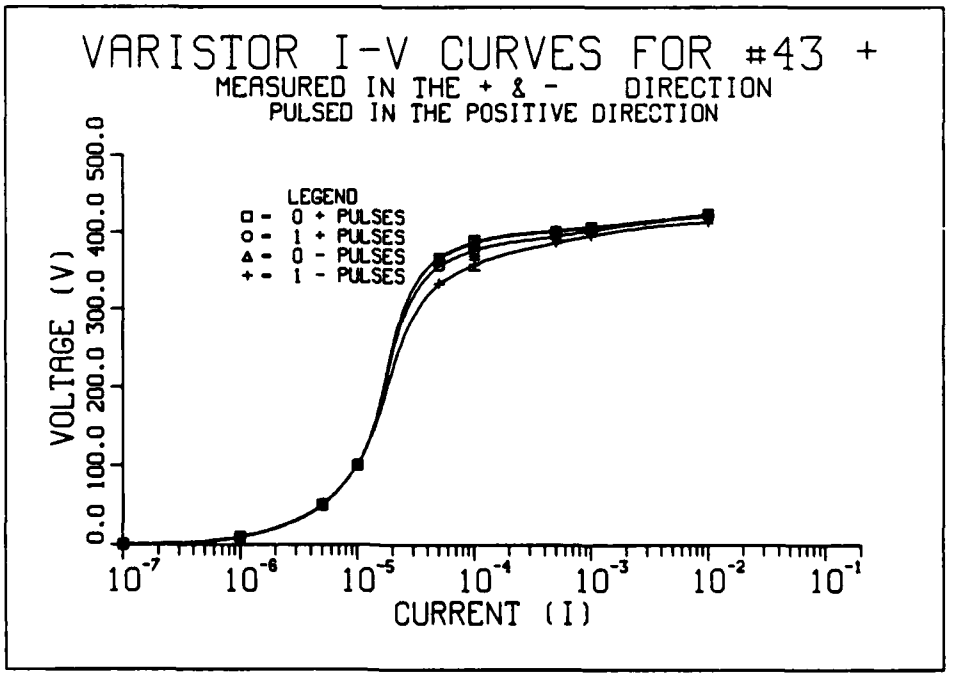

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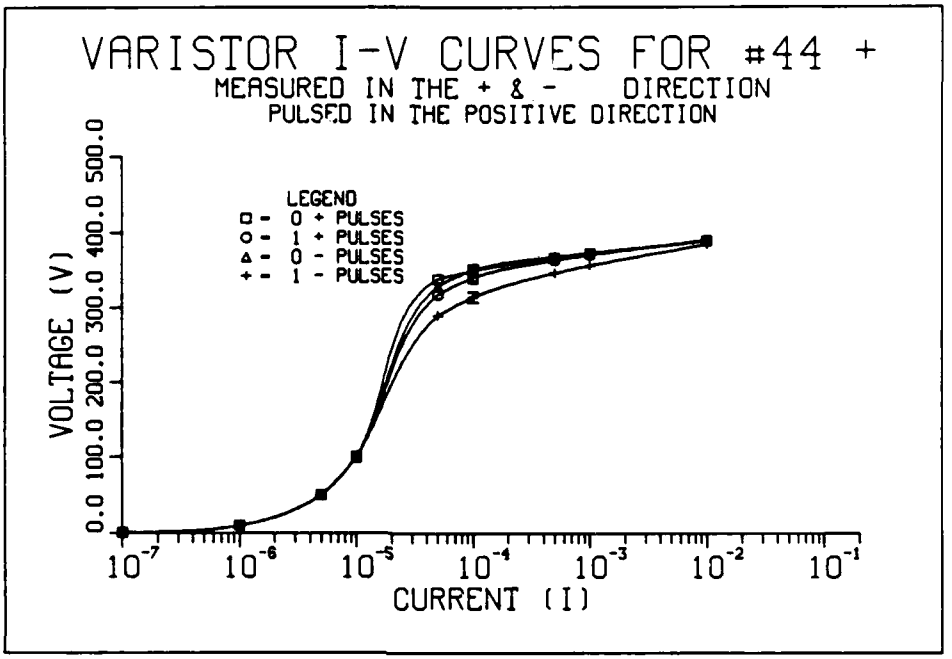

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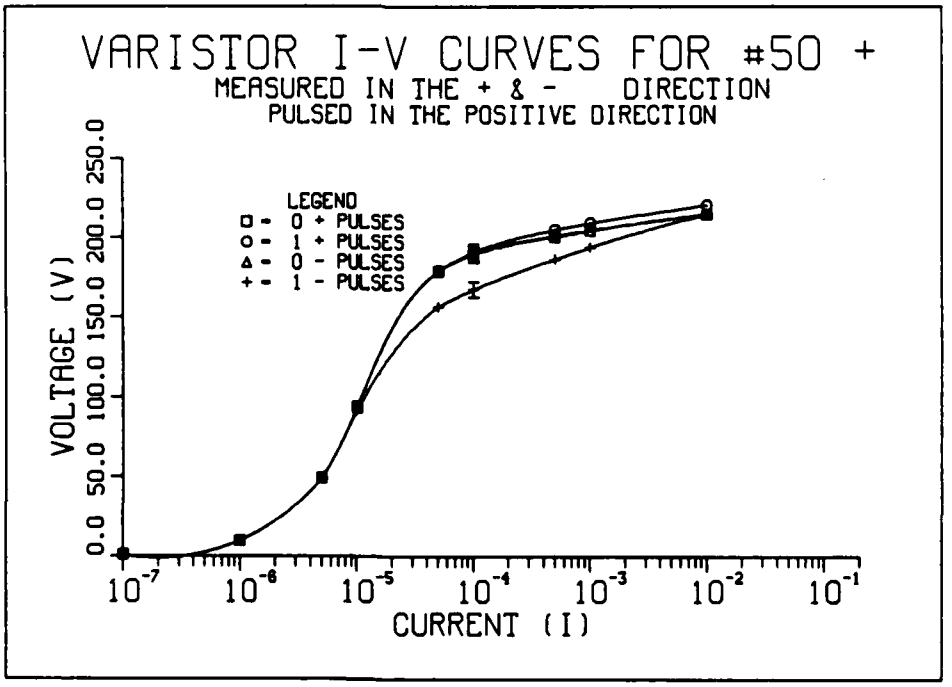

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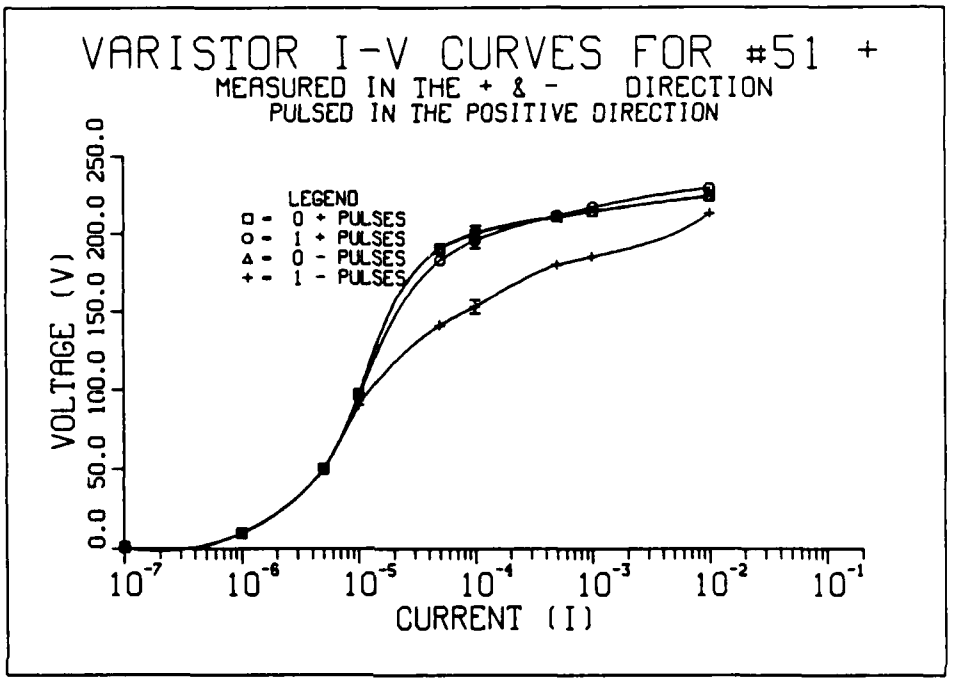

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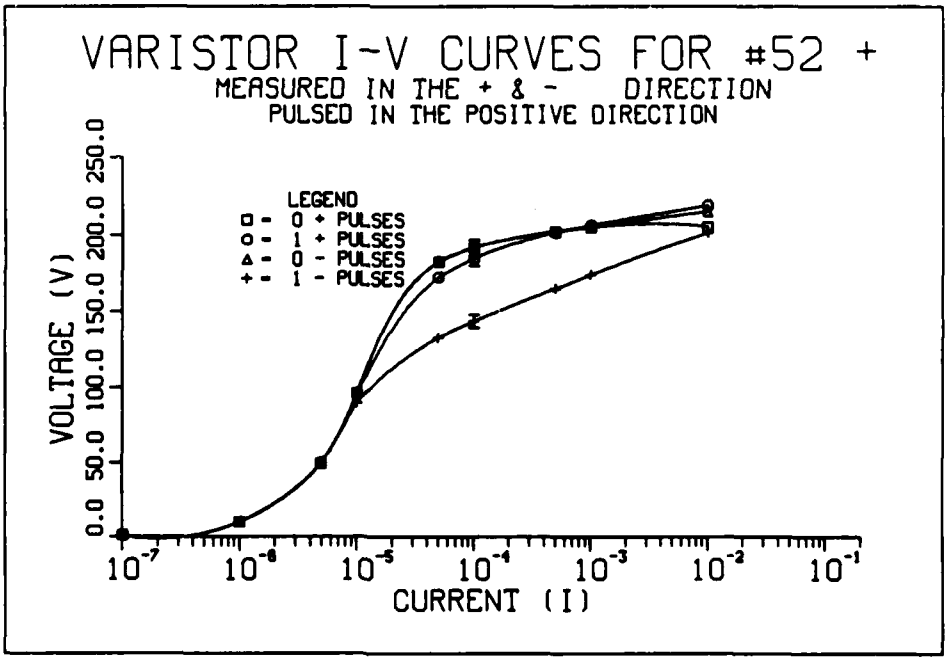

Figure 22.

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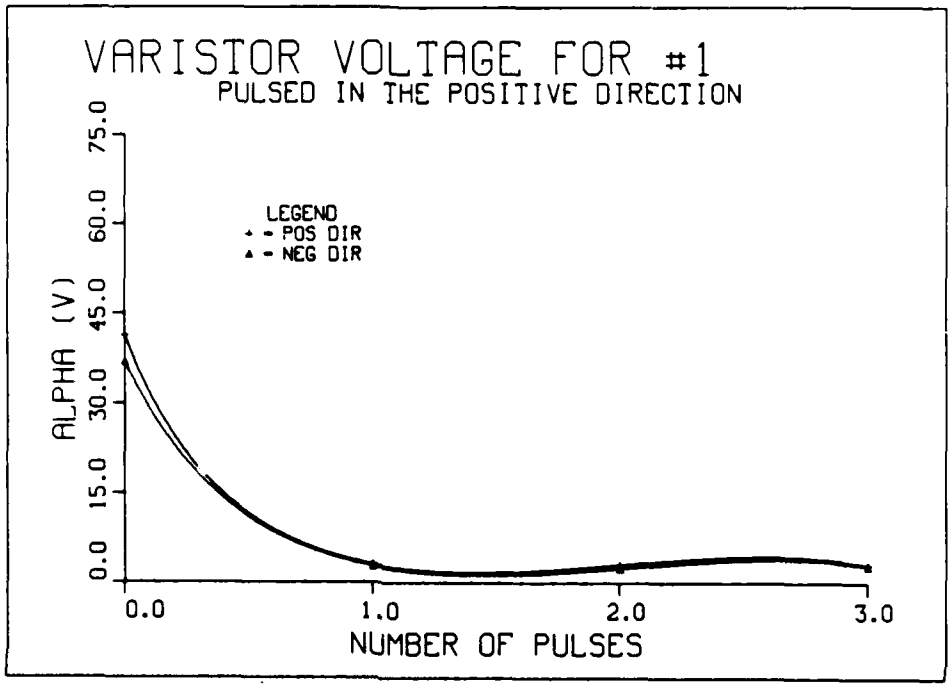
1. Hilland, D. H., Metal Oxide Varistor Burn-In, AFWL-TR-85-151, Air Force Weapons Laboratory, Kirtland Air Force Base, New Mex., September 1985 (approved for public release).

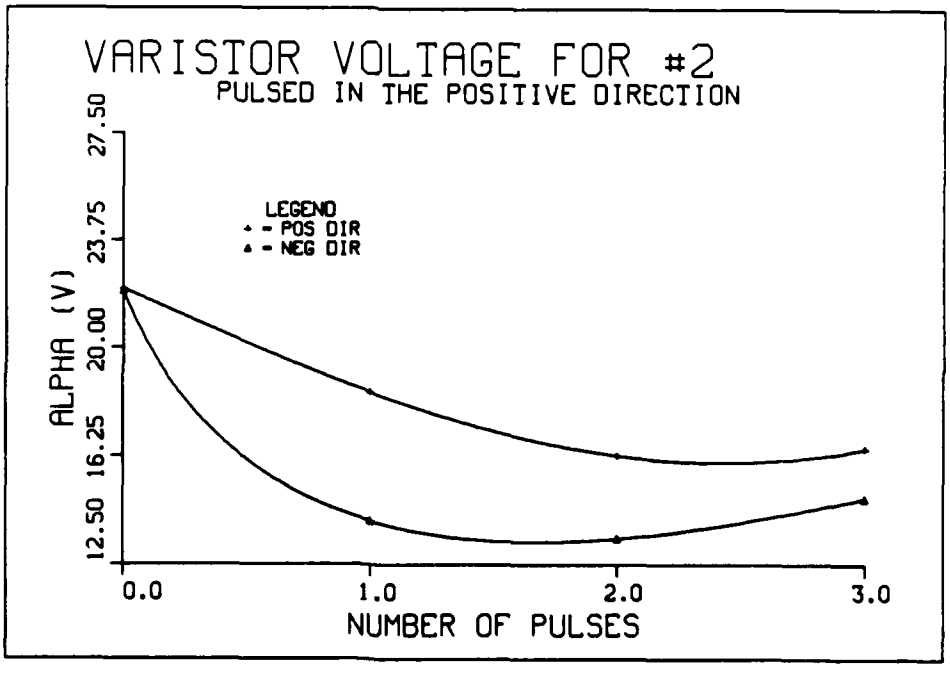
2. Golden, F., et al, Transient Voltage Suppression Manual, General Electric Company, Auburn, N.Y., 1983.

APPENDIX

VARISTOR ALPHA DEGRADATION CURVES

The curves in the appendix illustrate the degradation of the varistor figure of merit, alpha, as a function of measured polarity for a given pulsed polarity.


VARISTOR VOLTAGE FOR #1
PULSED IN THE POSITIVE DIRECTION
LEGEND
+ = POS DIR
▲ = NEG DIR
ALPHA (V)
0.0
15.0
30.0
45.0
60.0
75.0
0.0
1.0
2.0
3.0
NUMBER OF PULSES


VARISTOR VOLTAGE FOR #2
PULSED IN THE POSITIVE DIRECTION
LEGEND
+ = POS DIR
▲ = NEG DIR
ALPHA (V)
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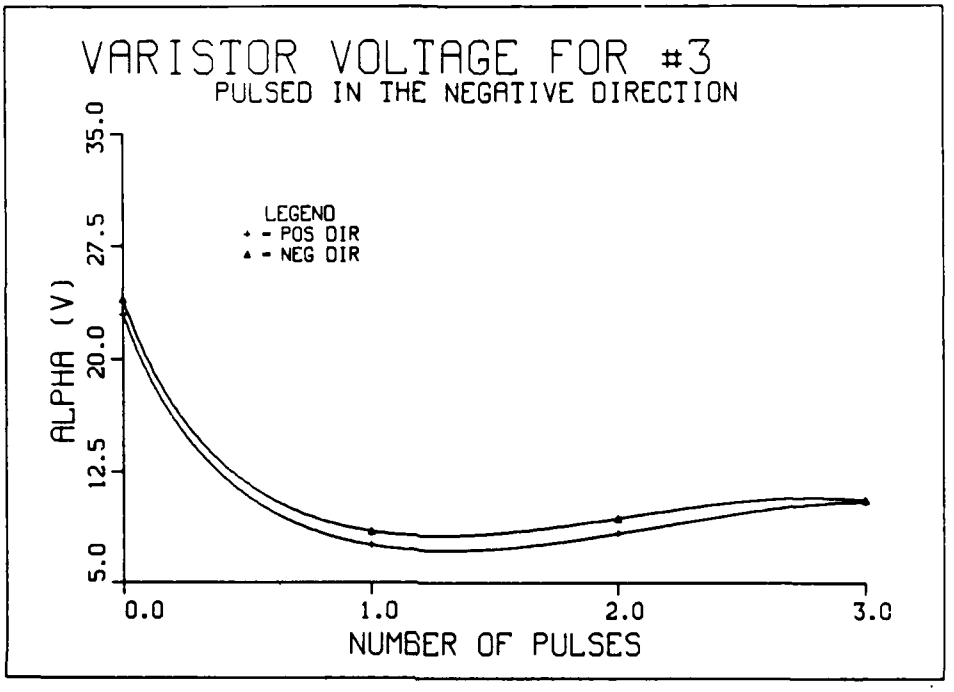
16.25
20.00
23.75
27.50
0.0
1.0
2.0
3.0
NUMBER OF PULSES


VARISTOR VOLTAGE FOR #3
PULSED IN THE NEGATIVE DIRECTION
LEGEND
+ - POS DIR
▲ - NEG DIR
ALPHA (V)
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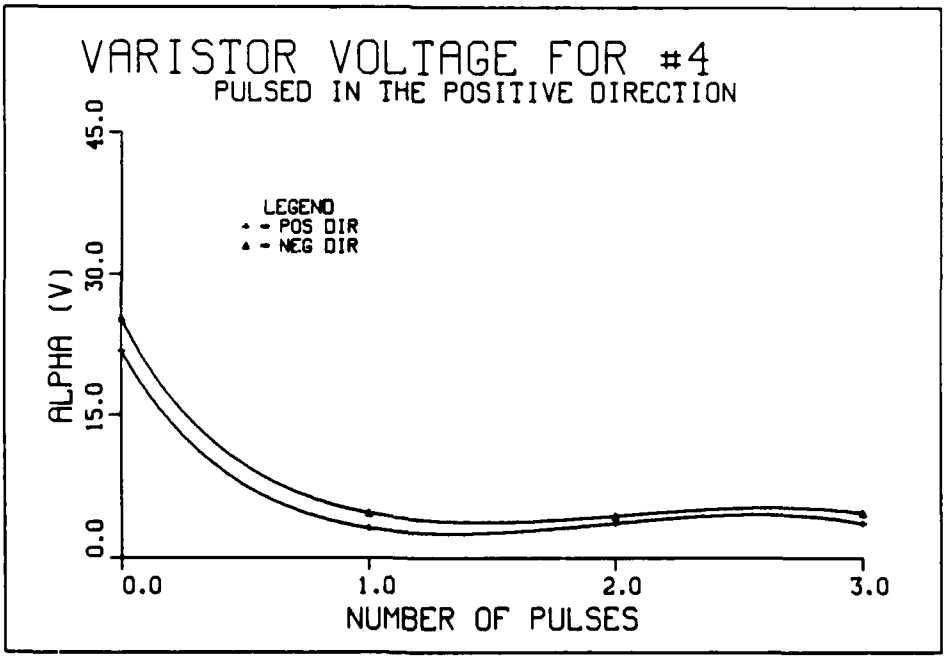
27.5
20.0
12.5
5.0
0.0
1.0
2.0
3.0
NUMBER OF PULSES


VARISTOR VOLTAGE FOR #4
PULSED IN THE POSITIVE DIRECTION
LEGEND
+ - POS DIR
▲ - NEG DIR
ALPHA (V)
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30.0
15.0
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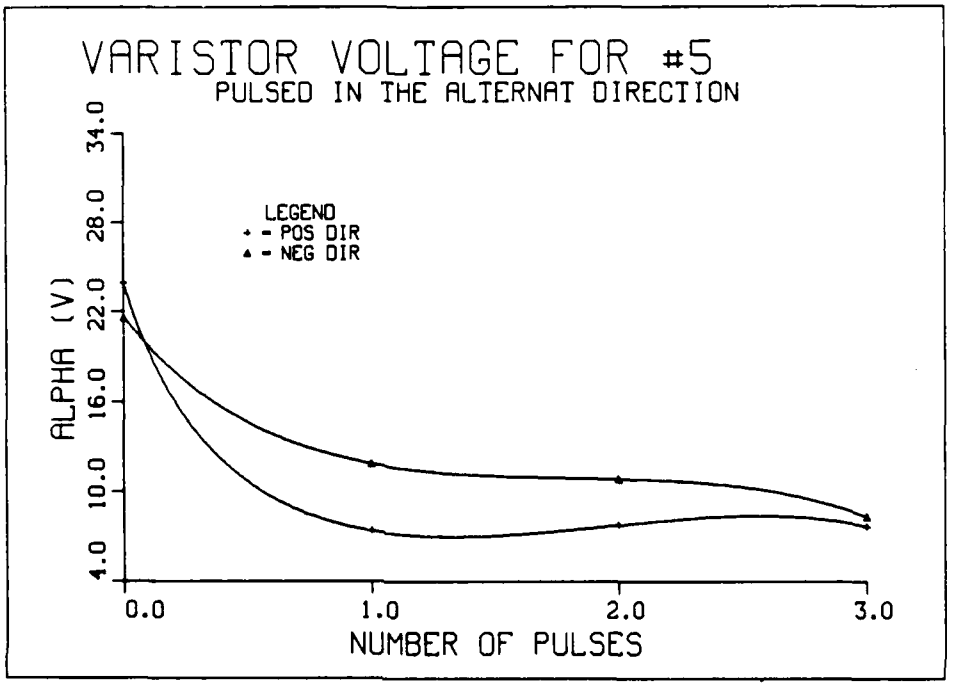
0.0
1.0
2.0
3.0
NUMBER OF PULSES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PULSED IN THE ALTERNAT DIRECTION
LEGEND
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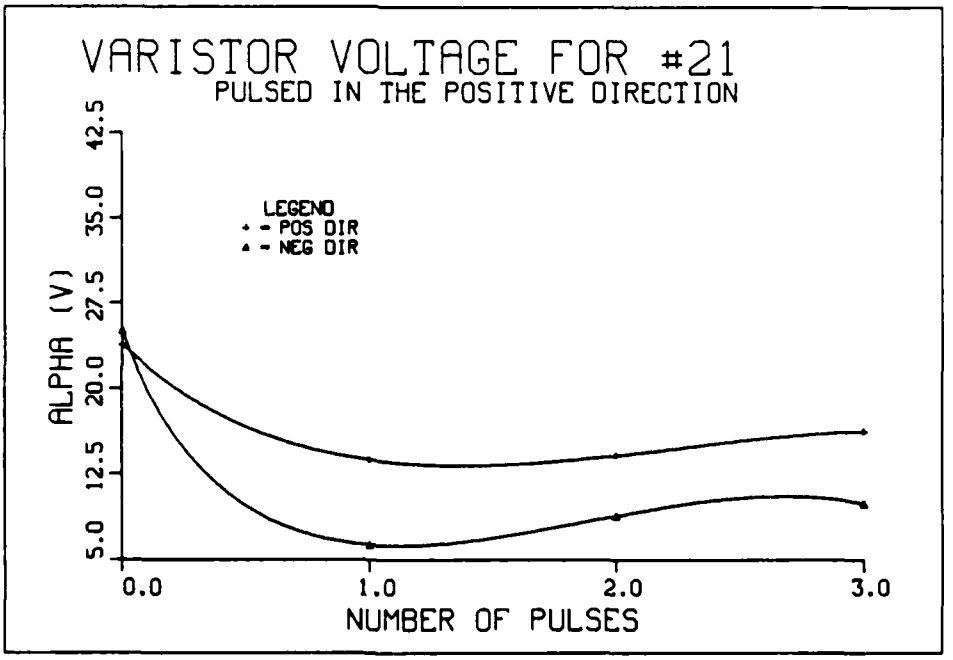
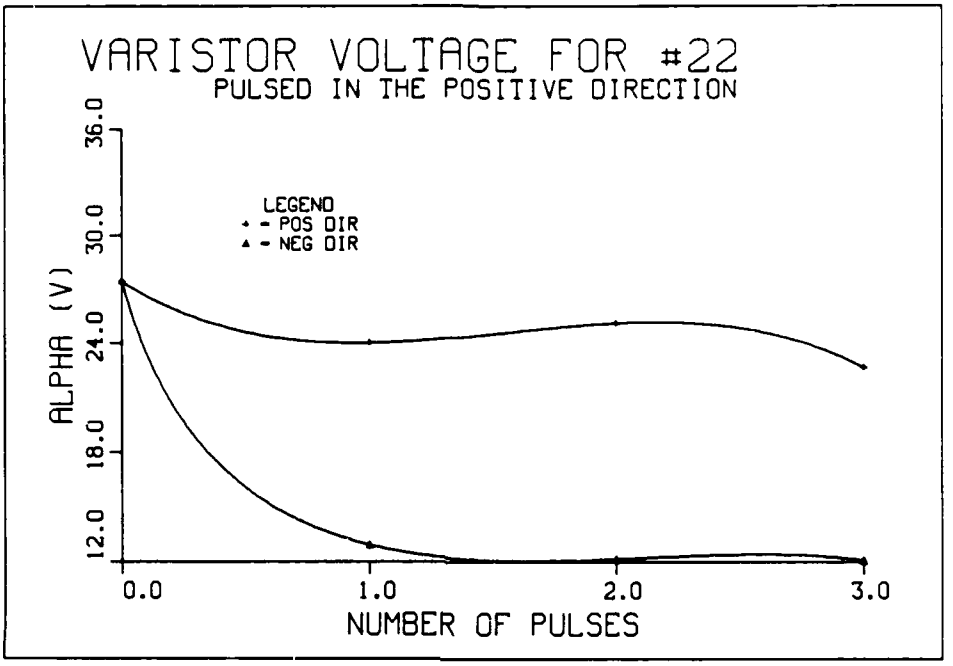
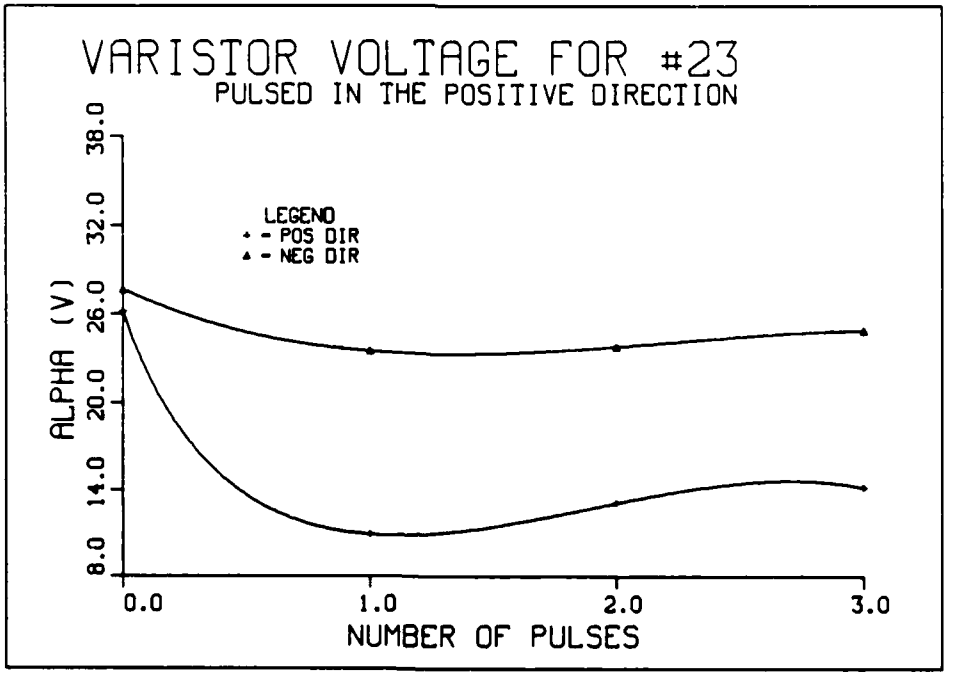
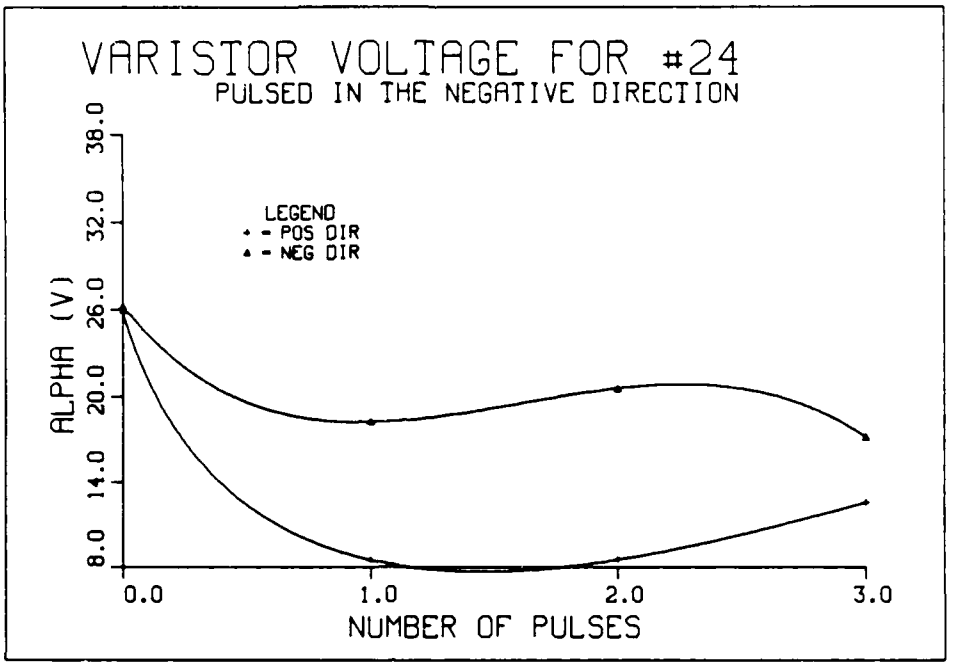
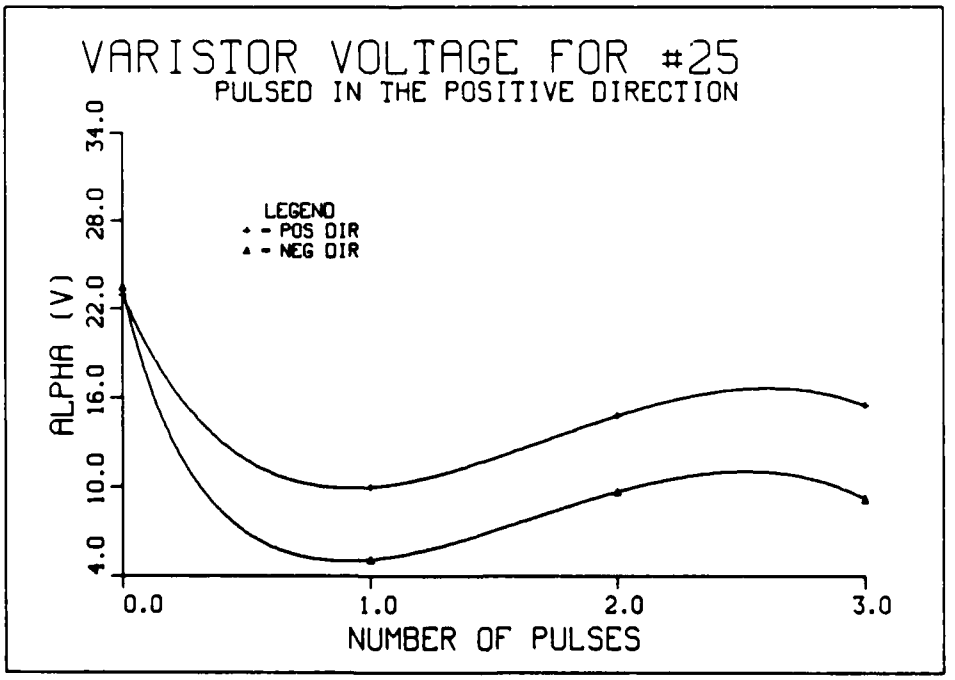
▲ - NEG DIR
ALPHA (V)
34.0
28.0
22.0
16.0
10.0
4.0
0.0
1.0
2.0
3.0
NUMBER OF PULSES

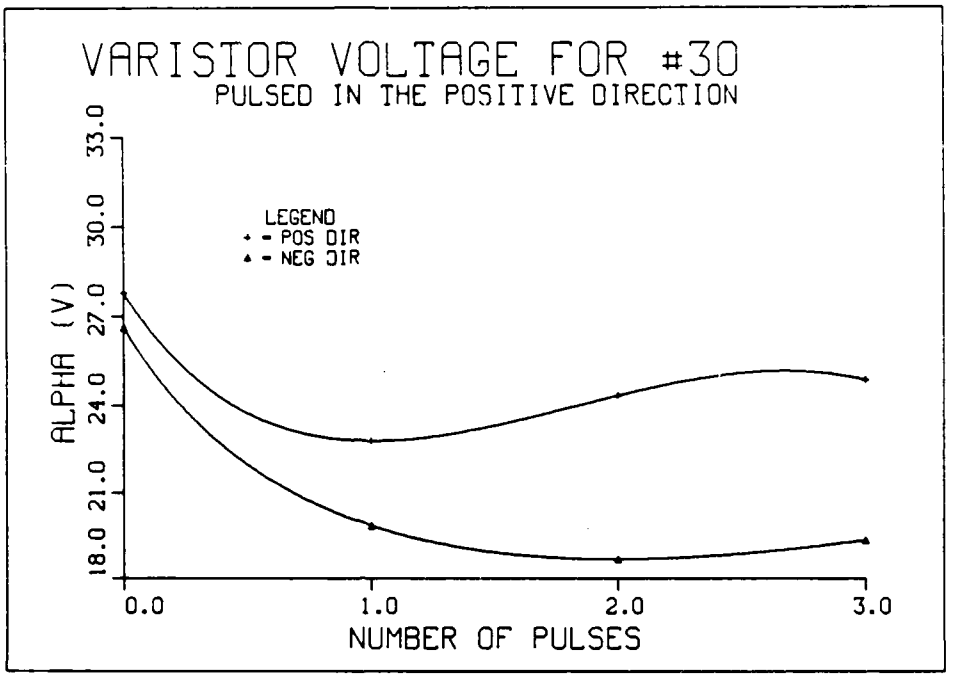

VARISTOR VOLTAGE FOR #21
PULSED IN THE POSITIVE DIRECTION
LEGEND
+ - POS DIR
▲ - NEG DIR
ALPHA (V)
42.5
35.0
27.5
20.0
12.5
5.0
0.0
1.0
2.0
3.0
NUMBER OF PULSES

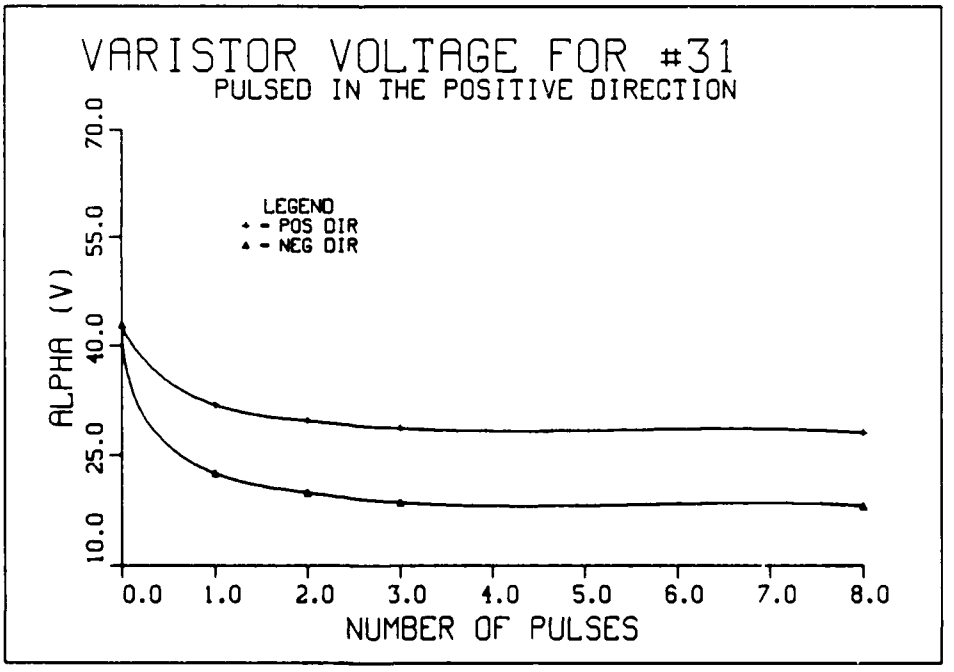

VARISTOR VOLTAGE FOR #22
PULSED IN THE POSITIVE DIRECTION
LEGEND
+ - POS DIR
▲ - NEG DIR
ALPHA (V)
36.0
30.0
24.0
18.0
12.0
0.0
1.0
2.0
3.0
NUMBER OF PULSES

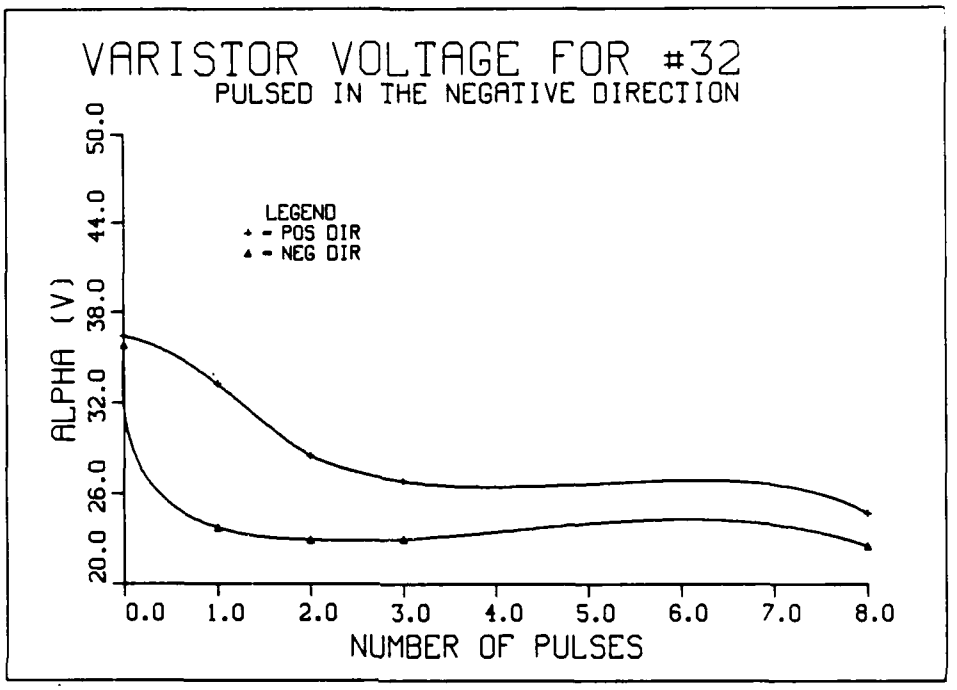

VARISTOR VOLTAGE FOR #23
PULSED IN THE POSITIVE DIRECTION
LEGEND
+ - POS DIR
▲ - NEG DIR
ALPHA (V)
38.0
32.0
26.0
20.0
14.0
8.0
0.0
1.0
2.0
3.0
NUMBER OF PULSES

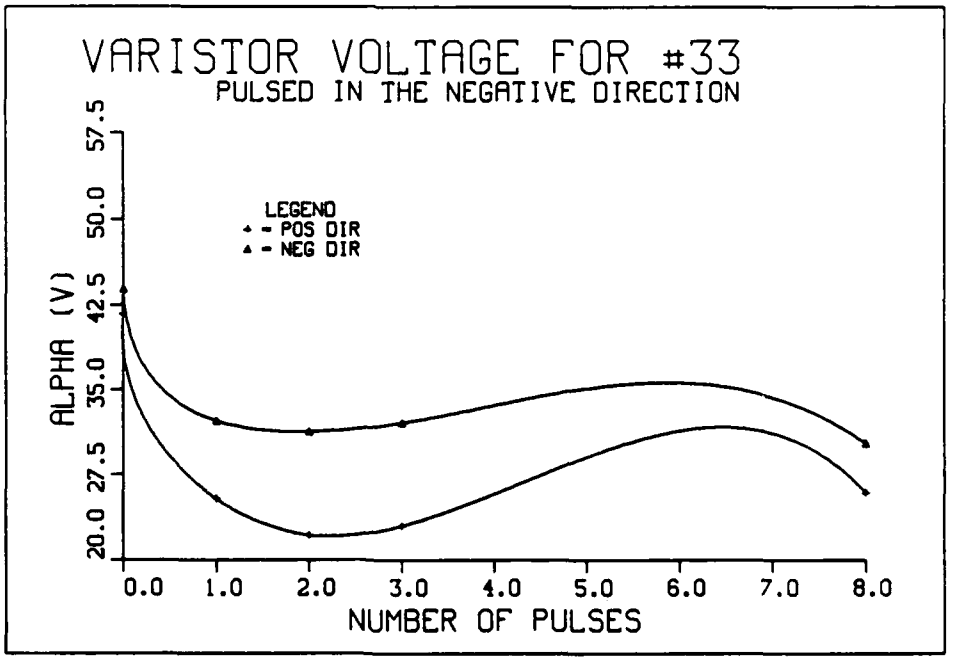

VARISTOR VOLTAGE FOR #24
PULSED IN THE NEGATIVE DIRECTION
LEGEND
+ - POS DIR
▲ - NEG DIR
ALPHA (V)
38.0
32.0
26.0
20.0
14.0
8.0
0.0
1.0
2.0
3.0
NUMBER OF PULSES

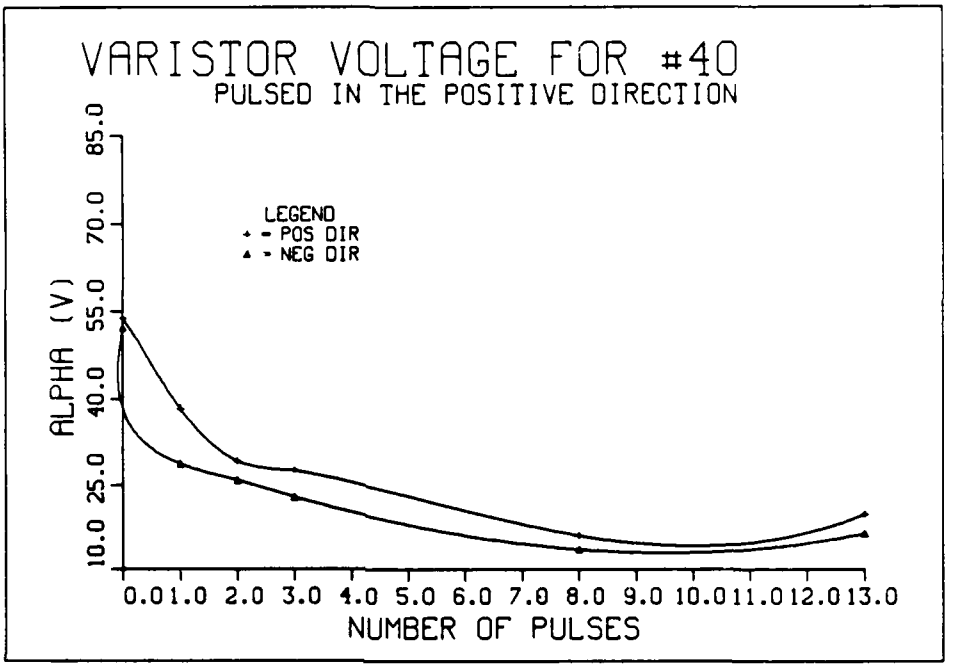

VARISTOR VOLTAGE FOR #25
PULSED IN THE POSITIVE DIRECTION
LEGEND
+ - POS DIR
▲ - NEG DIR
ALPHA (V)
34.0
28.0
22.0
16.0
10.0
4.0
0.0
1.0
2.0
3.0
NUMBER OF PULSES

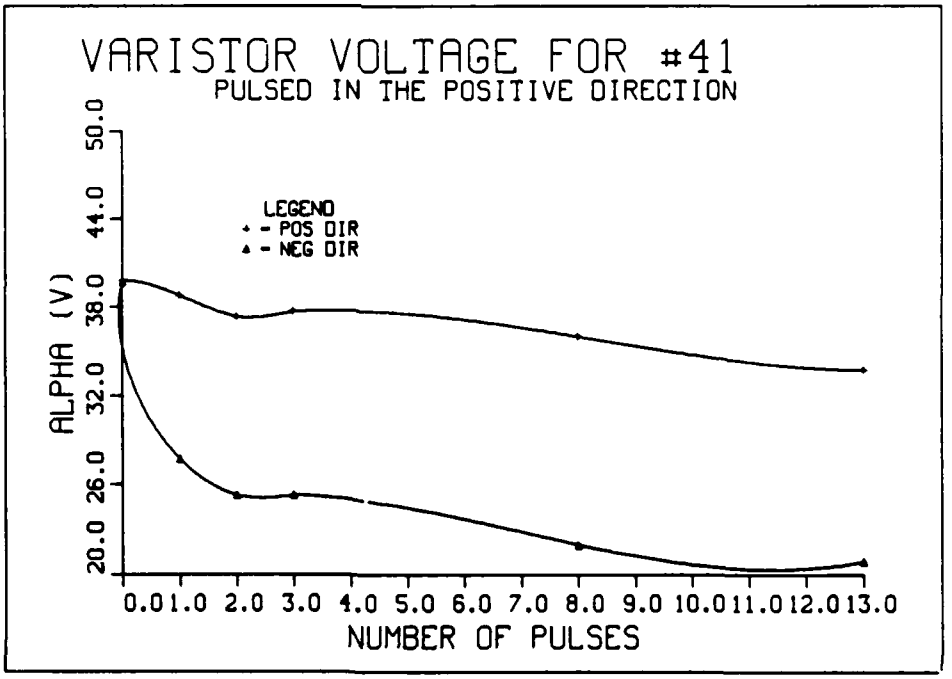

VARISTOR VOLTAGE FOR #30
PULSED IN THE POSITIVE DIRECTION
LEGEND
+ - POS DIR
▲ - NEG DIR
ALPHA (V)
18.0
21.0
24.0
27.0
30.0
33.0
0.0
1.0
2.0
3.0
NUMBER OF PULSES

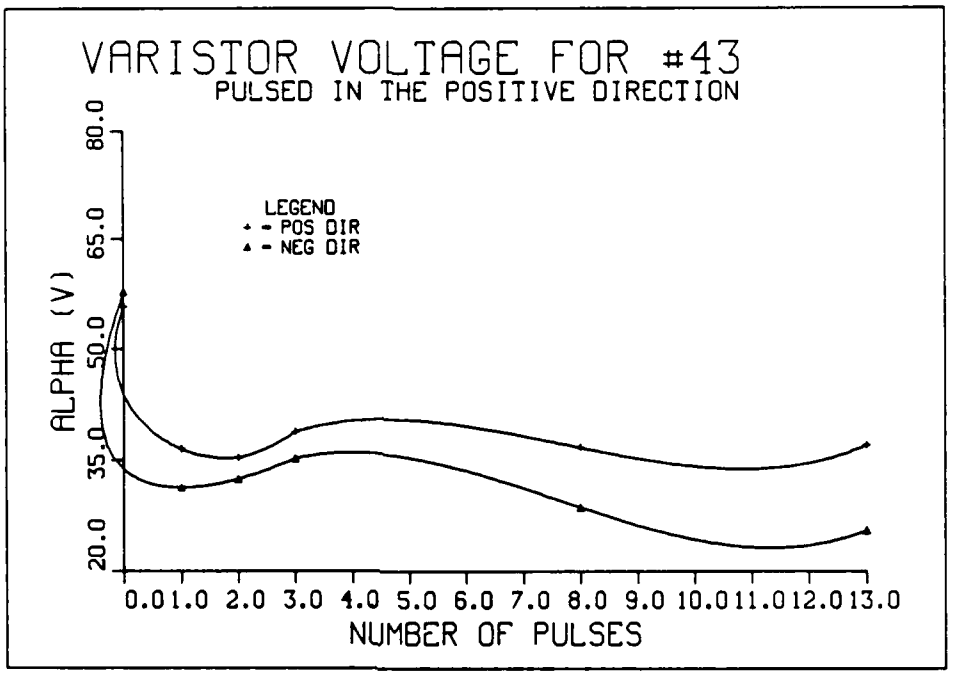

VARISTOR VOLTAGE FOR #31
PULSED IN THE POSITIVE DIRECTION
LEGEND
+ - POS DIR
▲ - NEG DIR
ALPHA (V)
10.0
25.0
40.0
55.0
70.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
NUMBER OF PULSES

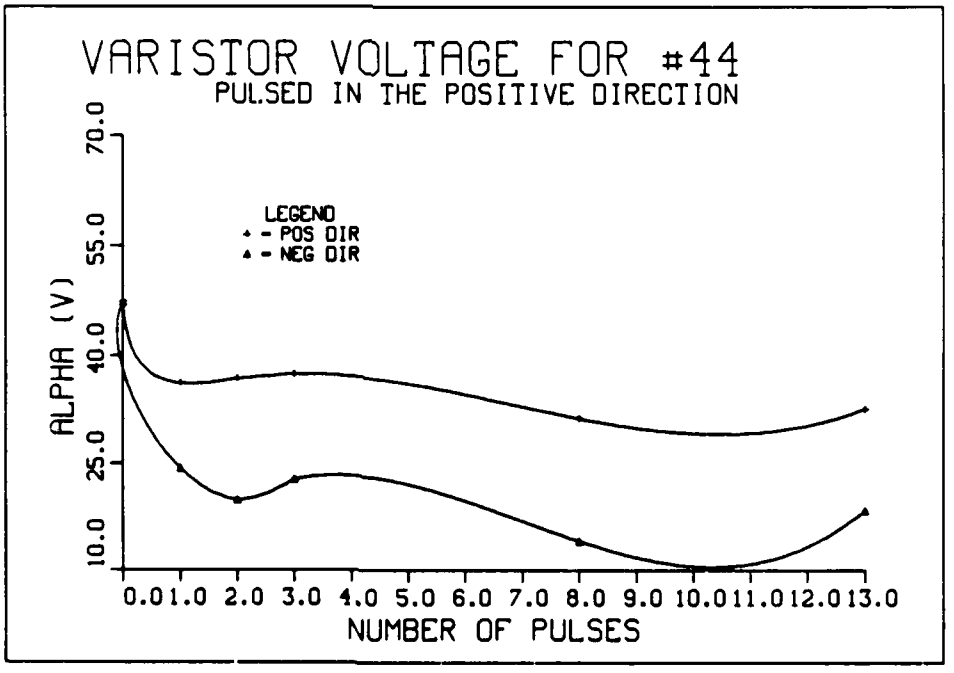

VARISTOR VOLTAGE FOR #32
PULSED IN THE NEGATIVE DIRECTION
LEGEND
+ - POS DIR
▲ - NEG DIR
ALPHA (V)
50.0
44.0
38.0
32.0
26.0
20.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
NUMBER OF PULSES

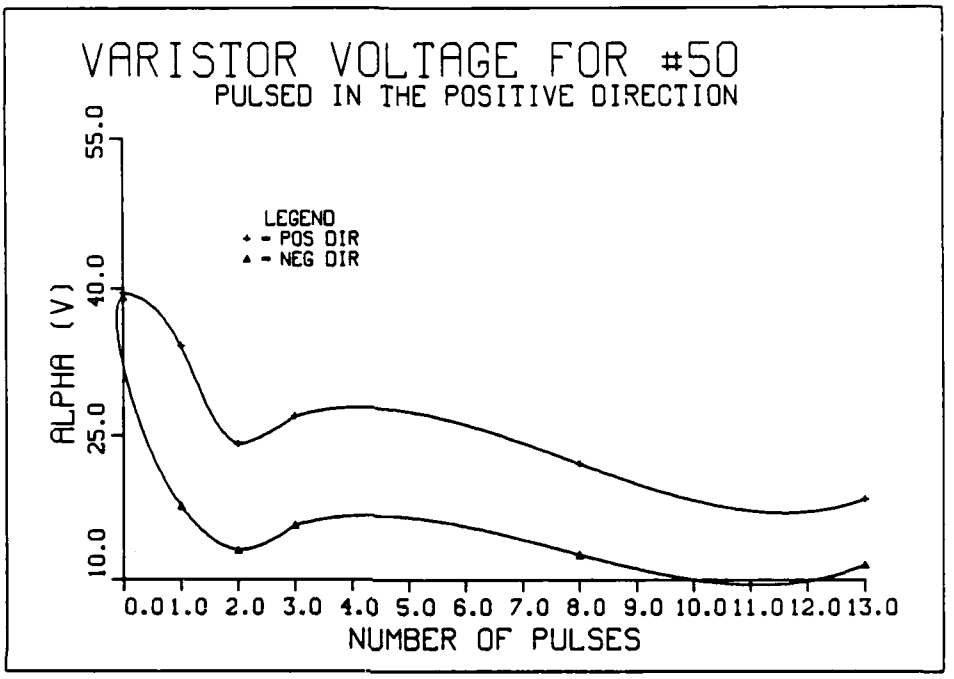

VARISTOR VOLTAGE FOR #33
PULSED IN THE NEGATIVE DIRECTION
LEGEND
+ - POS DIR
▲ - NEG DIR
ALPHA (V)
57.5
50.0
42.5
35.0
27.5
20.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
NUMBER OF PULSES

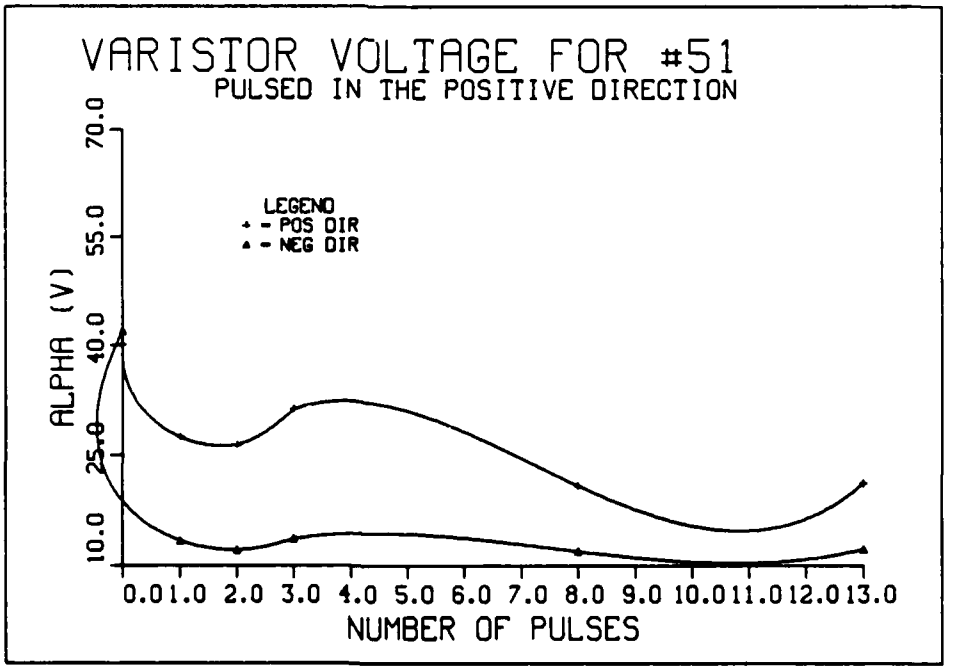

VARISTOR VOLTAGE FOR #40
PULSED IN THE POSITIVE DIRECTION
LEGEND
+ - POS DIR
▲ - NEG DIR
ALPHA (V)
10.0 25.0 40.0 55.0 70.0 85.0
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0
NUMBER OF PULSES

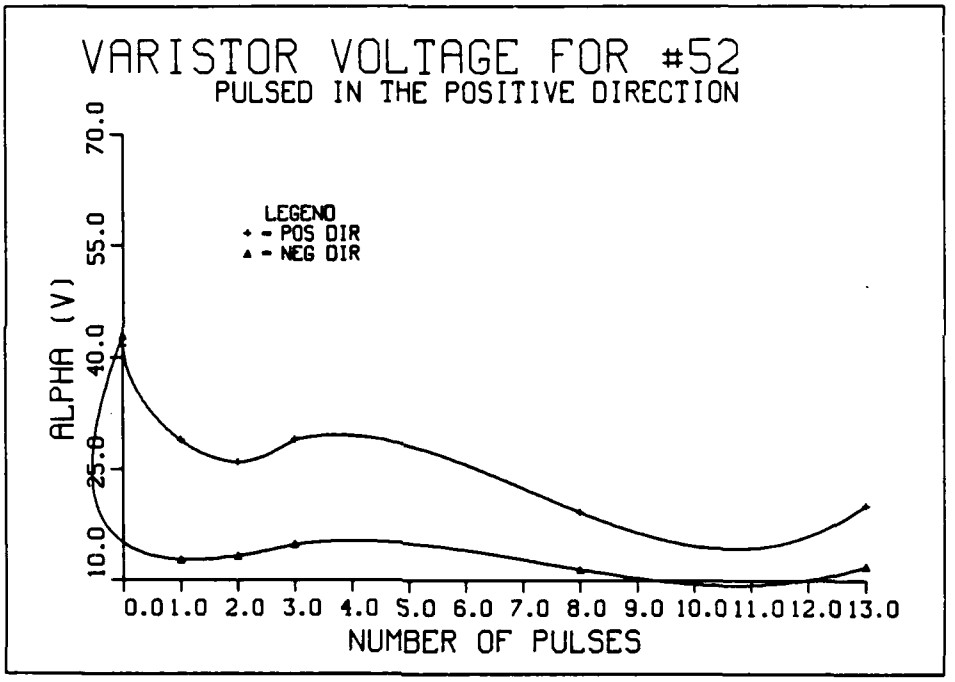

VARISTOR VOLTAGE FOR #41
PULSED IN THE POSITIVE DIRECTION
LEGEND
+ - POS DIR
▲ - NEG DIR
ALPHA (V)
20.0 26.0 32.0 38.0 44.0 50.0
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0
NUMBER OF PULSES


VARISTOR VOLTAGE FOR #43
PULSED IN THE POSITIVE DIRECTION
LEGEND
+ - POS DIR
▲ - NEG DIR
ALPHA (V)
80.0
65.0
50.0
35.0
20.0
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0
NUMBER OF PULSES


VARISTOR VOLTAGE FOR #44
PULSED IN THE POSITIVE DIRECTION
LEGEND
+ - POS DIR
▲ - NEG DIR
ALPHA (V)
70.0
55.0
40.0
25.0
10.0
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0
NUMBER OF PULSES


VARISTOR VOLTAGE FOR #50
PULSED IN THE POSITIVE DIRECTION
LEGEND
+ = POS DIR
▲ = NEG DIR
ALPHA (V)
55.0
40.0
25.0
10.0
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0
NUMBER OF PULSES


VARISTOR VOLTAGE FOR #51
PULSED IN THE POSITIVE DIRECTION
LEGEND
+ = POS DIR
▲ = NEG DIR
ALPHA (V)
70.0
55.0
40.0
25.0
10.0
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0
NUMBER OF PULSES


VARISTOR VOLTAGE FOR #52
PULSED IN THE POSITIVE DIRECTION
LEGEND
+ - POS DIR
▲ - NEG DIR
ALPHA (V)
70.0
55.0
40.0
25.0
10.0
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0
NUMBER OF PULSES

END
DATE
FILMD
3-88
DTIC